ECONOMICS OF PRAWN FARMING IN AUSTRALIA

J.R. PETER HARDMAN, RHONDA TREADWELL, AND GREG MAGUIRE

Hardman, J.R.P., Treadwell, R. and Maguire, G. 1991 09 01: Economics of prawn farming in Australia. *Memoirs of the Queensland Museum* 31: 421–434. Brisbane. ISSN 0079-8835.

The current structure of the prawn farming industry in Australia is defined, the costs of production are estimated and the importance of variation in yield, price, and cost of feed is determined. The importance of economies of size is also demonstrated.

A census conducted in November 1989 indicated that, during 1988–89, there were 25 farms using 249 ha of ponds stocked with marine prawns on the east coast of Australia. Almost all farms were established within the past five years. Total production increased rapidly during the 1980s, and in 1988–89, 351t of prawns (mainly *Penaeus monodon*) were produced.

Costs of production for two separate geographical locations were estimated as follows. First, using a combination of the census data and the opinions of informed growers, characteristics of representative farms were specified. Costs were then assigned to these farms based on actual grower experience. The results indicate that relative to current world prices and prospects, Australian costs of production are high. Sensitivity analyses indicate that farm profitability is very sensitive to price, yield and farm size. Though feed is an important component of total costs (12–38%), it requires a very large reduction in feed costs to significantly reduce the cost of production.

The overriding conclusion from the analysis is the high uncertainty of returns to prawn farming in Australia. Significant reductions in costs may be necessary, in view of the prospect of further price falls with the likely continued expansion of prawn aquaculture in South-East Asia. ☐ *Prawn farming, prawn aquaculture, profitability, costs of production, prawn farm economics.*

J.R. Peter Hardman, Queensland Department of Primary Industries, Brisbane, Queensland 4000, Australia; Rhonda Treadwell, Australian Bureau of Agricultural and Resource Economics, Canberra, Australian Capital Territory 2600, Australia; Greg Maguire, National Key Centre for Teaching and research in Aquaculture, University of Tasmania, Launceston, Tasmania 7250, Australia; 6 July, 1990.

Marine prawn farming industries have expanded dramatically in many tropical countries, so that by 1989 production from farms accounted for an estimated 26% of total prawn production from fisheries and farms (Rosenberry, 1990). Traditionally, prawns have been farmed in Asia at low stocking densities and with minimal management (less than 1 t/ha/y). However, technology has allowed farmers to increase stocking densities and production intensity to 'semi-intensive' (1–10 t/ha/y) and 'intensive' (more than 10 t/ha/y)(Wickins, 1976). Figures for the eight major prawn farming countries indicate that average yields per hectare are in the low to semi-intensive range (Rosenberry, 1990). Many Asian countries have greatly increased production through expansion of total ponded area and intensification of farming methods (Handley and Moore, 1989). In contrast, prawn farming has remained a small industry in Japan, and has grown slowly in other developed countries such as the United States, where farms are located in warm-temperate areas (Lawrence and Huner, 1987).

In Australia a few unsuccessful prawn farms were established before 1980 (Heasman, 1984). Subsequently, several farms were constructed in the warm-temperate area of northeastern New South Wales, stocked initially with school prawns (*Metapenaeus macleayi*) and later with leader prawns (*Penaeus monodon*). The latter is the main species stocked in farms which have been established in tropical and warm-temperate areas on the east coast of Queensland (Maguire and Allan, in press). Production of Australian farmed prawns rose rapidly to 351 t in 1988/89, and expectations of farmers indicate much greater production in 1989/90 (Potter and Jones, 1990). Despite such progress, the major factors affecting the economic viability of the Australian industry have yet to be analysed.

Several economic analyses have indicated that production costs for farmed prawns vary markedly between countries and with intensity of farming (Shang, 1983). Griffin *et al.* (1986) concluded that prawn farming would be more profitable in a tropical country than in a warm-temperate region. Though many economic assessments have been based on results from experimental rather than commercial prawn farming, those variables which are expected to most affect profitability have been identified. These include unpredictable environmental factors (Griffin *et al.*, 1981), stocking strategies, including density (Pardy *et al.*, 1983), species grown and polyculture (Huang *et al.*, 1984), farm and pond size (Hanson *et al.*, 1985), survival rate (Hollin and Griffin, 1986), use of passively heated nurseries (Juan *et al.*, 1988), and prawn sizes at stocking and harvest (McKee *et al.*, 1989). Most analyses have used deterministic models with single estimates for each variable, although stochastic modelling has been employed (Hansen *et al.*, 1985). This technique uses a range of estimates for each variable and provides a probability value for any particular rate of return. The relevance of risk analysis to prawn farming, particularly in relation to increasing intensity of farming and suboptimal seasons, has also been recognised (Hatch *et al.*, 1987). The collapse of the Taiwanese industry emphasises the importance of risk in prawn farming (Kwei, 1989).

The emphasis in Australian prawn farming research has been on developing appropriate technology rather than on economic analyses. Heasman (1984) adapted a US farm model (Parker and Hayenga, 1979) and applied this to a hypothetical *P. monodon* farm in north Queensland. Hardy (1985) predicted good returns for *M. macleayi* farms in northern New South Wales; Maguire and Leedow (1983) optimised stocking density and feed rate for that species using simple cash flow models. Cook and Lightfoot (1987) predicted attractive returns to farming *P. monodon* in north Queensland, based on model farms of 20 and 100 ha with a low stocking density (7 post larvae/m^2). Yang (1987) adapted a Taiwanese model using Australian cost data and demonstrated the importance of stocking density and survival rate to economic returns.

The approach taken in this study is as follows. First, the current and future market situation is reviewed. Next, the current structure of the prawn industry is determined by means of a census of prawn farmers. This in conjunction with input from farmer groups is used as a basis for specifying the prawn farm models. The models are specified to allow comparison between the tropical and warm-temperate farming regions and between intensities of operation. This is followed by the derivation of the costs of production and rates of return to prawn farming in Australia based on the model prawn farms. Sensitivity testing of results and stochastic analysis of returns are included, not only to demonstrate the risky nature of prawn farming at this stage but also to delineate the major variables which affect profit.

MARKET OUTLOOK

To date, most sales of Australian farmed prawns have been on the domestic market. The Australian prawn market closely follows trends in the international market, because over half of Australian production of wild caught prawns is exported (1988–89 exports being 11.5 kt: ABARE, 1989) and a similar volume is imported. Therefore the prices that Australian prawn farmers receive are largely set in the international marketplace. That market is influenced mainly by demand of the major importer, Japan, and the increasing world supply of cultured prawns. However, domestic prices do fluctuate with seasonal variations in supplies of wild caught prawns.

Asian countries provide more than 80% of the world's supply of cultured prawns. Around half of Asian cultured prawn production is *P. monodon*. In 1989 cultured prawn production by Asia reached 500 kt, almost double that of 1987 (Rosenberry, 1990). This increase was largely due to a rise in production of *P. monodon* by Thailand and Indonesia. China remains the largest producer of cultured prawns with 220 kt in 1989, but, after recent large increases, production in China appears to be stabilising in 1990, reportedly due to disease problems (Anon., 1989). However, total Asian production of cultured prawns is expected to continue to expand and has been forecast to reach 800 kt by the year 2000 (Anon., 1988). Such an increase would continue to put downward pressure on prices.

On the demand side, Japan is the major world importer of prawns and absorbs most of Australia's exports of prawns (around 80%). Australia has very limited influence on the Japanese market, accounting for only about 5% by value of Japanese imports (Battaglene and Kingston, 1990). The major suppliers to the Japanese market are the Asian countries. At the same time as supplies of prawn have increased, the growth in Japanese consumption of seafood has slowed. Although seafood's share of Japanese meat and seafood consumption has fallen from 74% in 1960 to 44% in 1985 (Kingston *et al.*, 1990), prawn consumption did increase between 1984 and 1987 from 2.5 kg to 3 kg per person a year. However, the increased supply of prawns has exceeded the moderate increase in consumption, the result being a 90% increase in cold storage holdings since 1984 and falling prices on the Japanese market. If prices continue to fall the quantity demanded is likely to rise.

In the longer term there appears to be no relief from lower prices on the Japanese market, because aquaculture production is expected to rise in Asia. Currently, Australian cultured prawns are mainly sold in Australia in bulk through wholesalers, and most production is of *P. monodon*. Thus, these sales would be in direct competition with the Asian cultured prawns, whether on the Australian or world markets. There are options which would enable Australian producers to remain in this very competitive market. Prawn farmers may be able to time production to take advantage of seasonal fluctuations, and thus obtain higher prices by supplying the market when alternative supplies are low. Efforts could be directed to supplying a reliable, high quality, well-presented product, but this would raise marketing costs. Alternatively, management could be directed at producing larger prawns which command a premium in the marketplace. Although 25 g prawns are sold in Australia there is a limited export market for this small size. If production continues to expand, farmers may need to assess the option of larger prawns for the export market. Another option is to supply larger, fresh or live prawns to the restaurant trade, which offers a significant premium over the supermarket or commodity market, particularly in Japan. In addition, farmers could switch production from the commonly produced *P. monodon* to the culture of higher-priced species such as *P. japonicus* or *P. esculentus*. Such a switch in production would require development of appropriate farming methods for these species.

STRUCTURE OF THE PRAWN FARMING INDUSTRY IN AUSTRALIA

The industry is small but expanding rapidly (Fig. 1). Gross value of production could reach $12 million in 1989–90 (O'Sullivan, 1990). Queensland has replaced New South Wales as the major producer of farmed prawns, mainly due to the faster growth rates achievable in the higher water temperatures. Production in other states is negligible.

The majority of Australian farms are < 10 ha, with a few large farms responsible for most of the production. The region between Townsville and Cairns contains 55% of Queensland's farms, while Mackay has 22% and Brisbane region 11%. The greatest growth in farm area is occurring in the Townsville-to-Cairns region.

The data in Table 1 indicate a rapid development process in the prawn industry as evidenced by the following changes from 1988–89 to 1989–90:

- a 23% increase in total ponded area (all within Queensland);
- a 60% increase in total stocked area;
- a 28% increase in stocking density.

The wide range between farms for most of the parameters used for measuring productivity (stocking rate, feed conversion ratio and yield) also indicates the developmental stage of the industry. In addition, the average feed conversion ratio of 2.265:1 (feed weight to product weight) is significantly higher than overseas results which suggest that long term averages of 1.8:1 or better can be achieved (Chen *et al.*, 1989).

Due to the current rapid development phase it is difficult to define a model or average prawn farm for analytical purposes. Regression analysis of farm parameters yielded two statistically significant relationships: as farm size increased, so did pond size ($R^2 = 0.58$, $p < 0.001$) and the number of ponds ($R^2 = 0.59$, $p < 0.001$). No other statistically significant relationships were found in regression analyses including farm parameters such as yield, stocking density and feed conversion ratio ($p > 0.05$). That is, the industry has not developed sufficiently for a clear management pattern to emerge.

With the assistance of prawn farmers, the representative model prawn farm was defined to be six 1 ha ponds as a family farm unit (Table 2). Although this is less than the industry average of 15 ha, the majority of farms are < 10 ha with a few very large farms of up to 95 ha. The 6 ha farm was considered to be representative of most farms, particularly in far north Queensland (FNQ). For comparative purposes the growers in the northern New South Wales/southeast Queensland region (NSW/SEQ) accepted the basic 6 x 1 ha prawn model as defined by FNQ growers, although farms tend to be larger in NSW/SEQ. The most obvious difference between the regions is the number of crops per year, the NSW/SEQ region usually hav-

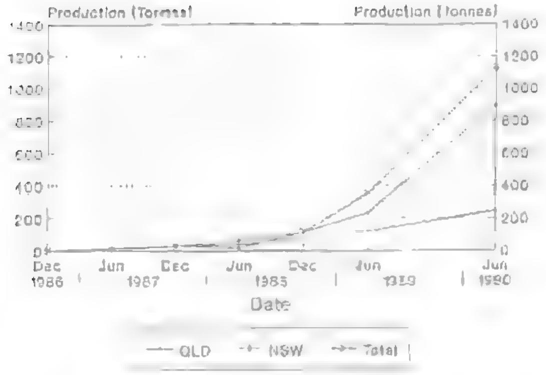

FIG. 1. Production from Australian prawn farms 1986–90. *Source*: Queensland Department of Primary Industries, ABARE and Allan (1989a). *Note*: December 1989 to June 1990 — estimated productions.

ing only one crop a year while two crops a year was considered achievable in FNQ.

Farm operation intensity was defined in terms of stocking density. Two stocking densities, low and high, were accepted as representative. The model low stocking density (8 post larvae (PL)/m²) falls within the range reported for Australian prawn farms in 1988, of 5–15 PL/m² (Robertson, 1988). As is seen from Table 1, stocking density increased again between 1988/89 and 1989/90. The model high stocking density (25 PL/m²) was chosen to reflect this trend. The low stocking density model was considered by farmers to depict a learning stage rather than a long term farming proposition. For these low densities substantially larger ponds are more appropriate (Scura, 1987)

In the model farms, both survival rates and growth rates declined with increasing stocking density (Table 2). Accordingly, for the lower stocking density the average prawn size at harvest was set higher than for the high stocking density. This relationship between growth and density accords with experimental results reported by Allan and Maguire (1988). However, they concluded that survival rates were not affected by stocking density in their experimental ponds. This indicates that yields may be improved in the future as farmers gain more experience in feeding regimes and pond management.

COSTS OF PRODUCTION

Costs were estimated for the 6 x 1 ha farm model by farmers who attended group assessment meetings held in far north Queensland and northern New South Wales, with additional information from equipment suppliers.

Feed is by far the largest component of annual operating costs, accounting for 57% for the high density model farm in far north Queensland (Table 3). Prawn fry is the other major operating cost, comprising about 20% for the low density farms and 23% for the high density farms.

The major costs of establishment are land and earthworks (Table 4). To achieve six 1 ha ponds a total land area of 12 ha would be required to allow provision of sheds, roadways and channels. The cost of surveying and constructing ponds varies markedly ($12 000–40 000/ha), depending principally on topography, soil type, wall slope and pond configuration. For the model farm of six 1 ha ponds a flat site with a suitable clay base was assumed and a corresponding cost of $20 000/ha used in the analyses. The cost of a pumping system also varies substantially, depending on the level of water exchange required, tidal limitations and the desired speed of filling. It is feasible that farmers could install cheaper pumping systems than those listed in Table 4.

The total establishment cost of around $0.5 million including land purchase (Tables 5 and 6) constitutes a substantial obstacle. However, in the case of sugar cane farmers who enter prawn farming, these capital costs may be considerably reduced through the use of existing surplus land, equipment and possibly underutilised labour. Table 4 outlines costs for a farm of twenty 1 ha ponds. These figures are used below in an investigation of economies of scale.

Total production costs for the low stocking density model are shown in Table 5. In the NSW/SEQ region, the total cost of production, at $15.67/kg, is too high given current market prices and outlook. In far north Queensland, with two crops a year, the production cost is much lower, at $9.38/kg. For the high density farms (Table 6) the difference between regions is much less, with FNQ costs of production $1.54 lower than those in NSW/SEQ. These costs are very close to current market prices. In early 1990 the farm gate price for 25 g prawns varied in the range $8–12/kg, with an average price of $10/kg. Prices increase with the size of prawn, and 30 g prawns fetched about $2/kg more. Therefore, in the analyses prices were varied according to the size of prawn produced (Tables 2, 5 and 6).

Given the possibility of further price falls in the future, it is important to examine the opportunities for reducing costs. The cost of feed may be lowered in two ways: by a drop in the cost of feed per tonne, or by a decrease in the feed

TABLE 1. Prawn Farming Industry: census results.

Variable	Total ponded area	Total number of ponds	Average area of ponds	Stocked area	Stocking density	Feed conversion ratio	Total production	Average yield per unit stocked area(a)
Units	ha	no.	ha	ha	no. PL m^{-2}		t	t/ha/y
1988–89								
Total for all farms	369.9	235		248.55			350.75	
Range for all farms	0.8–95	1–40	0.4–3.5	0.45–50	5–30	1.5–4.6:1	0.4–62	0.07–6.8
Average for all farms	14.8	9.4	1.57	9.94	12.72	2.7:1	14.03	1.41
1989–90								
Total for all farms	455.5	nc		397.1			1130(p)	
Range for all farms	0.8–95	nc	nc	0.8–95	5–35	nc	4–280(p)	1–13.5(p)
Average for all farms	15.16	nc	nc	13.23	16.27	nc	37.67(p)	2.85(p)

Source: Telephone census, November 1989, of all known prawn farmers in Queensland and New South Wales (25 farms). (a) Average yields per stocked area in 1988/89 were mainly based on one crop per year. Only 3 out of 25 farmers double cropped. Average yields per stocked area in 1989/90 are higher than 1988/89 in part because 14 out of 30 farmers indicated their intention to double crop. nc= data not collected. p= projected by Queensland Department of Primary Industries, ABARE and Allan (1989a). PL= post larvae (prawn fry).

TABLE 2. Description of model 6 x 1 ha pond prawn farms.

		Low stocking density		High stocking density	
Item	Units	FNQ	NSW/SEQ	FNQ	NSW/SEQ
Aeration		No	No	Yes	Yes
Number of crops/year	no	2	1	2	1
Average size of prawns	g	27.5	30	25	25
Stocking rate	PL/m^2				
- average		8	8	25	25
- range		6–10	6–10	20–30	20–30
Survival rate	%				
- average		70	50	60	60
- range		80–60	56–50	70–50	60–57
Yield	t/ha/y				
- average		3.08	1.2	7.5	3.75
- range		2.6–3.3	1.0–1.5	7.0–7.5	3.0–4.3
Production	t/6 ha/y	18.48	7.2	45	22.5

Source: Group assessment meetings, South Johnstone, Queensland, and Palmers Island, New South Wales, March 1990. FNQ, Far north Queensland. NSW/SEQ, New South Wales and south-east Queensland.

TABLE 3. Annual operating costs: 6 x 1 ha pond farm model.

Item	Units	Low Stocking Density		High Stocking Density	
		FNQ	NSW/SEQ	FNQ	NSW/SEQ
Number of crops/year	no.	2	1	2	1
Total production	t/y	18.48	7.2	45	22.5
Feed conversion ratio		1.8:1	1.3:1	2.25:1	1.8:1
Feed consumed	t/y	33.26	9.36	101.25	40.5
Total feed cost @ $1500/t	$	49 896	14 040	151 875	60 750
Cost of prawn fry @ 2c	$	19 200	9 600	60 000	30 000
Casual labour	$	8 000	8 000	13 000	10 000
Electricity	$	10 000	3 000	22 000	12 000
Fertiliser	$	3 000	1 500	5 000	1 500
Repairs & maintenance	$	8 000	8 000	10 000	8 000
Miscellaneous	$	3 000	3 000	4 000	4 000

Source: Group assessment meetings: for FNQ, South Johnstone Research Station, Queensland, and for NSW/SEQ, Palmers Island, New South Wales.

conversion ratio. It is evident from the sensitivity tests that it would require a very large saving in feed costs to effect a significant reduction in production costs (Table 7). For example, to effect a saving of about 50c/kg in the total cost of production requires a decrease in feed cost of between 15% (for the FNQ high intensity farm) and 25% (for the low intensity farm in the NSW/SEQ region). Such large cost savings may be difficult to achieve. However, reductions in feed conversion ratios can be effected through more appropriate feed rates (Allan, 1989b).

Yields per hectare may be raised by either increasing the stocking density and/or improving the survival and/or growth rates. The sensitivity tests reported here were based on increasing the stocking density, with feed conversion ratios held constant and no change in survival or growth rates. (The savings in costs would be larger if the same yield increase were achieved at least partly by improved survival and/or growth rates). To achieve a saving of around $1/kg in the total cost of production would require an increase in yield of between 8% (for the low density NSW/SEQ farm) and about 30% (for the high density FNQ farm) (Table 8). This latter increase would imply a yield from two crops totalling 9.8 t/ha/y. Such an increase may be achievable in the future if improved pond management allows higher stocking densities as well as better survival and growth rates.

Economies of size may offer a further option for reducing the unit cost of production. A larger farm of twenty 1 ha ponds with high stocking density was analysed (Table 9). The unit costs of production for the larger farm model are almost 20% lower than for the 6 x 1 ha farm model. This result is not surprising, given that overhead costs comprise 33–46% of total costs for the high density 6 x 1 ha farms (Table 6). Similar size economies are likely for low density farms, for which overhead costs account for an even greater share of total costs.

RATES OF RETURN TO PRAWN FARMING

The previous sections have shown that costs and yields in prawn farming in Australia vary with region and stocking density. Account must also be taken of the high degree of uncertainty surrounding prices, costs and yields for similar farms within the same region. A rate of return based only on the most likely estimates does not fully reflect the nature of returns to prawn farming.

Sensitivity testing over the range of possible values for the uncertain parameters would become unwieldy and difficult to interpret. The alternative approach used in this paper is stochastic investment analysis. This approach is based on the stochastic analysis of returns to new horticultural crops by Treadwell and Woffenden (1984).

The analysis uses the estimated range for each uncertain parameter — that is, for costs, market prices and the parameters set out in Table 2. For each simulation, a value (or a fluctuating time series) was randomly generated for each parame-

TABLE 4. Capital costs for model prawn farms with 1 ha ponds, for both regions.

Item	Total value: 6 ha farm, Low density $	Total value: 6 ha farm, High density $	Total value: 20 ha farm, High density $	Scrap value %	Years when purchased y
Earthworks (ponds & channels)	120 000(a)	120 000(a)	300 000(b)	–	0
Pump(s)	15 000	30 000	40 668	10	0,5,10,15
Motor(s)	4 000	8 000	40 667	10	0,5,10,15
Belts, pulleys, pump base, etc.	2 500	5 000	6 665	–	0,3,6,9,12,15,18
Pump shed, valves, filters	10 360	10 360	15 200	–	0
Pipes, gates, screens, boards	24 000	24 000	80 000	–	0
Electric power supply	40 000	80 000	200 000	–	0
Generator (standby)	5 000	10 000	20 000	10	0,10
Rotary hoe	–	3 000	5 000	10	0,10
Spike tooth harrows	1 000	1 000	2 000	10	0,10
Slasher	1 500	1 500	2 000	10	0,10
Bucket	–	1 000	5 000	10	0,10
Blade	1 000	1 000	1 500	10	0,10
Fertiliser spreader	2 500	2 500	2 500	10	0,10
Farm truck (2nd hand)	20 000	20 000	20 000	10	0,10
Tractor (2nd hand)	10 000	10 000	15 000	10	0,10
Motorbike	–	2 000	2 000	10	0,5,10,15
Blower pipe (feed)	1 000	[illegible]	1 000	–	0,3,6,9,12,15,18
Aeration units	–	33 000	135 000	10	0,5,10,15
Refrig. plant, esky, bins, etc	8 000	14 000	22 000	10	1,11
Ice machine (1 t/day)	13 000	13 000	13 000	10	1,11
Prawn weighing scales	500	1 000	2 500	–	1,4,7,10,13,16,19
Harvest equip (nets/cages)	1 500	2 500	4 000	–	1,4,7,10,13,16,19
Prawn handling area & equip. (washes, trays, loader)	8 000	10 000	10 000		1,11
Farm shed	10 000	15 000	25 000	–	0
Tools	2 000	5 000	10 000	–	0,5,10,15
Test kits	2 000	4 500	4 500	–	0,3,6,9,12,15,18
Boat (2nd hand)	1 500	1 500	2 500	10	0,10
Office equipment	3 000	3 000	3 000	–	0,5,10,15
Miscellaneous	2 000	3 000	5 000	–	0,5,10,15

(a) Plus purchase of 12 ha of land, at $6000/ha in FNQ region and $4000/ha in NSW/SEQ.
(b) Plus purchase of 35 ha of land at same prices as in (a).

ter from its observed distribution. Each such set of parameter values was used to calculate a specific stream of costs and returns, from which the internal rate of return was derived. This procedure was repeated a large number of times (700), to generate a set of internal rates of return (IRR). These were then ranked and their cumulative probability function was calculated. This function gives the probability of the internal rate of return being less than any particular level.

The advantage of this stochastic approach is that it not only produces the expected or mean internal rate or return but also indicates the effect of uncertainty by providing the range of internal rates of return with their corresponding probabilities of occurrence. This procedure avoids the need for sensitivity analysis on individual parameters, as the overall uncertainty is reflected in the probability distribution of internal rates of return. However, individual sensitivity tests can still be undertaken to show the specific effect of variation in a particular parameter.

The stochastic investment analysis was conducted for the four prawn farm models using the

TABLE 5. Cost of production: low stocking density system.

Item	FNQ		NSW SEQ	
PHYSICAL DESCRIPTION				
Number of ponds	6		6	
Area/pond (ha)	1		1	
Total farm area (ha)	12		12	
Production/crop (t/ha)	1.54		1.2	
Number of crops/year (no.)	2		1	
Total production of prawns (t/y)	18.48		7.2	
Feed conversion ratio	1.8:1		1.3:1	
Feed consumed (t/y)	33.26		9.36	
Capital costs of establishment(a)($)	380 360		356 360	
FINANCIAL DESCRIPTION	$/y	$/kg	$/y	$/kg
Gross income	203 280	11.00	86 400	12.00
Operating costs				
— Feed	49 896	2.70	14 040	1.95
— Casual labour	8 000	0.43	8 000	1.11
— Electricity	10 000	0.54	3 000	0.42
— Prawn fry	19 200	1.04	9 600	1.33
— Fertiliser	3 000	0.16	1 500	0.21
— Repairs & maintenance	8 000	0.43	8 000	1.11
— Miscellaneous	3 000	0.16	3 000	0.42
Total operating costs	101 096	5.47	47 140	6.55
Overhead costs				
— Depreciation & interest(b)	40 214	2.18	38 774	5.39
— Allow. for farmer's labour	26 090	1.41	20 872	2.90
— Permanent hired labour	0	0	0	0
— Administrative costs	6 000	0.32	6 000	0.83
Total overhead costs	72 304	3.91	65 646	9.12
Total costs	173 400	9.38	112 786	15.67
Ratio of overhead to total costs (%)		42		58
Return to management	29 880	1.62	-26 386	-3.67

(a) Derived from Table 4 plus land purchase. (b) Assuming real rate of interest 6%.

estimated range in parameter values as set out in previous sections. The analysis was on a pre-tax basis, using private costs and benefits, and was conducted over 20 years, the estimated life of ponds. The analysis was based on the following assumptions.

- Costs do not change relative to prices during the period of analysis — that is, constant (1989–90) values are used.
- The interest rate on money borrowed equals the internal rate of return.
- During the period of analysis, no technical changes occur which result in major increases in yields or substantial changes in the relationship between yields and costs.
- There is no correlation between prices, yields and costs (as Australian prawn farms supply only a minor segment of the market).
- Full production is possible from the first year of operation.
- The farm is well managed and located on a suitable site with ready access to water. There are no disasters such as would cause total loss of crop.

The effects of the last two assumptions, in particular, is that the average internal rates of return generated will be higher than the industry average. The results will reflect more closely the results of more experienced farmers with suitable sites, rather than the average of a new and expanding industry.

The cumulative probability distributions for the four prawn model farms are summarised in Table

TABLE 6. Costs of production: high stocking density system.

Item	FNQ		NSW/SEQ	
PHYSICAL DESCRIPTION				
Number of ponds	6		6	
Area/pond (ha)	1		1	
Total farm area (ha)	12		12	
Production/crop (t/ha)	3.75		3.75	
Number of crops/year (no.)	2		1	
Total production of prawns (t/y)	45		22.5	
Feed conversion ratio	2.25:1		1.8:1	
Feed consumed (t/y)	101.25		40.5	
Capital costs of establishment(a)($)	507 860		483 860	
FINANCIAL DESCRIPTION	($/y)	($/kg)	($/y)	($/kg)
Gross income	450 000	10.00	225 000	10.00
Operating costs				
— Feed	151 875	3.38	60 750	2.70
— Casual labour	13 000	0.29	10 000	0.44
— Electricity	22 000	0.49	12 000	0.53
— Prawn fry	60 000	1.33	30 000	1.33
— Fertiliser	5 000	0.11	1 500	0.07
— Repairs & maintenance	10 000	0.22	8 000	0.36
— Miscellaneous	4 000	0.09	4 000	0.18
Total operating costs	265 875	5.91	126 250	5.61
Overhead costs				
— Depreciation & interest(b)	61 663	1.37	60 223	2.68
— Allow. for farmer's labour	26 090	0.58	20 872	0.93
— Permanent hired labour	37 500(c)	0.83	20 000(d)	0.89
— Administration costs	6 000	0.13	6 000	0.27
Total overhead costs	131 253	2.92	107 095	4.76
Total cost	397 128	8.83	233 345	10.37
Ratio of overhead to total costs (%)		33		46
Return to management	52 872	1.18	-8 345	-0.37

(a) and (b) as for Table 5. (c) Equivalent of 1.5 full-time people. (d) Equivalent of 0.8 full-time person.

10. The highest average internal rate of return is that for the high density farm in north Queensland, followed closely by the low density farm in north Queensland. The uncertainty of the returns is similar for these two types of operation, as is shown by their respective cumulative probability functions (Fig. 2). As noted above, the low stocking density model was considered to be a developmental stage and not a long term proposition. This is certainly true for the NSW/SEQ region, where the low density model did not generate positive returns.

The difference in returns between the two regions is notable, with the internal rates of return for NSW/SEQ falling well below those for FNQ. The higher profitability of the tropical region

FIG. 2. Cumulative probability of IRR: 6 ha prawn farm models.

TABLE 7. Estimated costs of production resulting from decreases in feed cost.

Reduction in feed cost	Low density system		High density system	
	FNQ	NSW/SEQ	FNQ	NSW/SEQ
%	$/kg	$/kg	$/kg	$/kg
0	9.38	15.67	8.83	10.37
10	9.11	15.47	8.49	10.10
15	8.98	15.37	8.32	9.96
20	8.84	15.28	8.15	9.83
25	8.71	15.18	7.98	9.69
30	8.57	15.08	7.82	9.56

corresponds with worldwide experience (Griffin *et al.*, 1986). The sensitivity of returns to the number of crops indicates a need to research the necessary requirements (in addition to climate) which facilitate two crops a year. Few farmers produced two crops in 1988/89. Options worthy of consideration include three crops in two years in the FNQ region — with perhaps a larger sized prawn being harvested than is obtainable at two crops a year — or, in the NSW/SEQ region, the production of one prawn crop per year while using the same ponds for other aquacultural products such as oysters in the cooler months (Maguire *et al.*, 1981).

A significant difference between the regions in practice is that prawn farms in NSW/SEQ tend to be larger than those in FNQ, and larger than the 6 x 1 ha pond operation used in this analysis. Therefore, a larger farm of twenty 1 ha ponds was simulated. The expected internal rate of return for the larger farm is more than double that for the small farm. This indicates the existence of significant economies of size in prawn farming. (There may be similar economies in relation to pond size, but that question would require further research which was not possible in this study.)

As in the previous section on costs, the sensitivities of rates of return to a 10% drop in feed costs and a 10% increase in yields were analysed, and the results are summarised in Table 10. Again, the 10% drop in feed costs has a smaller effect on returns than a 10% increase in yields (Fig. 3). For example, for the low density FNQ farm the average rate of return rose by 26% in response to the 10% increase in yield but rose only by 9% given a 10% drop in feed cost.

Another very uncertain factor is the market outlook. Rather than prices remaining constant relative to costs it is probable that relative prices may fall, in view of the continuing expansion of prawn aquaculture, particularly in South-east Asia. If prices were to fall continuously at an annual rate of 1.5%, returns to prawn farming would be expected to fall substantially. For instance, mean returns to the high density NSW/SEQ 6 x 1 ha farm model fell below zero (Table 10). For the twenty 1 ha NSW/SEQ farm model the mean return was less than half that derived with constant prices. However, in the face of a continual price decline prawn farmers would be likely to improve yields and/or reduce costs to offset the effects of the price fall, as has occurred in other primary production activities.

Overall, the simulated distribution of returns to prawn farming indicates that it is a very un-

TABLE 8. Estimated costs of production resulting from an increase in yield.

Yield increase	Low density system		High density system	
	FNQ	NSW/SEQ	FNQ	NSW/SEQ
%	$/kg	$/kg	$/kg	$/kg
0	9.38	15.67	8.83	10.37
10	8.87	14.53	8.45	9.78
15	8.64	14.04	8.29	9.53
20	8.44	13.59	8.14	9.30
25	8.29	13.17	8.00	9.09
30	8.07	12.79	7.87	8.89

TABLE 9. Costs of production for 20 x 1 ha farm with high stocking density.

Item	FNQ		NSW/SEQ	
PHYSICAL DESCRIPTION				
Number of ponds	20		20	
Area/pond ha	1		1	
Total farm area ha	35		35	
Production/crop t/ha	3.75		3.75	
Number of crops/year no.	2		1	
Total production of prawns t/y	150		75	
Feed conversion ratios	2.25:1		1.8:1	
Feed consumed t/y	337.5		135	
Capital costs of establishment(a) $	1 218 200		1 148 200	
FINANCIAL DESCRIPTION	$/y	$/kg	$/y	$/kg
Gross income	1 500 000	10.00	750 000	10.00
Operating costs				
—Feed	506 250	3.38	202 500	2.70
—Casual labour	45 000	0.30	22 500	0.30
—Electricity	73 300	0.49	40 000	0.53
—Prawn fry	200 000	1.33	100 000	1.33
—Fertiliser	16 700	0.11	5 000	0.07
—Repairs & maintenance	15 000	0.10	12 000	0.16
—Miscellaneous	6 000	0.04	6 000	0.08
Total operating costs	862 250	5.75	388 000	5.17
Overhead costs				
— Depreciation & interest(b)	141 937	0.95	137 737	1.84
— Allow. for farmer's labour	26 090	0.17	26 090	0.35
— Permanent hired labour(c)	75 000	0.50	75 000	1.00
— Administration costs	11 000	0.07	11 000	0.15
Total overhead costs	254 027	1.69	249 827	3.33
Total costs	1 116 277	7.44	637 827	8.50
Ratio of overhead to total costs (%)		23		39
Return to management	383 723	2.56	112 173	1.50

(a) Derived from Table 4 plus land purchase. (b) Assuming real rate of interest of 6%. (c) 3 full-time people.

FIG. 3. Cumulative probability of IRR: far north Queensland 6 ha high density prawn farm model.

certain business. For example, the average internal rates of return on the two modelled 6 ha North Queensland farms are 16.8% and 13.8%, but there is a 25% chance that the return could fall below those averages by over a third. In addition, variations in prices, yields, feed costs and the size of farm have very marked effects on returns.

CONCLUSIONS

The principal aim of this study was to provide industry statistics and an analysis of the economics of prawn farming to assist industry, government and researchers to determine future directions. In 1989–90 Australian production of cultured prawns came from 30 farmers with al-

TABLE 10. Internal rates of return to prawn farming: stochastic simulations.

Farm model*		Mean	75% probability that IRR is more than:	75% probability that IRR is less than:
		%	%	%
Low density:	FNQ	13.8	10.0	17.6
	NSW/SEQ	–	–	–
High density:	FNQ	16.8	10.5	22.8
	NSW/SEQ	2.0	–	7.0
Feed costs reduced by 10 percent				
Low density:	FNQ	15.1	11.4	19.4
	NSW/SEQ	–	–	–
High density:	FNQ	20.2	13.8	25.6
	NSW/SEQ	3.6	–	8.4
Yields increased by 10 percent				
Low density:	FNQ	17.4	13.6	21.0
	NSW/SEQ	–	–	–
High density:	FNQ	21.0	15.2	27.4
	NSW/SEQ	5.2	–	10.7
Prawn prices deflated by 1.5% a year				
Low density:	FNQ	6.1	0.2	11.1
	NSW/SEQ	–	–	–
High density:	FNQ	4.2	–	13.3
	NSW/SEQ	–	–	–
20 x 1 ha pond farm, high density				
Constant prices:	FNQ	39.2	30.6	47.2
	NSW/SEQ	15.9	9.6	21.6
Prawn prices deflated by 1.5% a year:				
	FNQ	31.4	20.6	40.2
	NSW/SEQ	6.4	–	14.2

* 6 x 1 ha except where otherwise indicated. — Negative.

most 400 ha of ponds along the east coast. The industry is undergoing rapid change as it expands and develops beyond the infant stage and a clear management pattern has not yet emerged.

The economic analyses were based on a 6 x 1 ha model prawn farm with two intensities of operations in two regions, far north Queensland and New South Wales/south-east Queensland. Given the risks and lead time associated with developing a new industry, the establishment costs of about $0.5 million per farm present a large obstacle. Overhead costs are 33–46% of total costs for the high intensity farm, so it is not surprising that there are substantial economics in operating a larger farm as indicated by the results from a 20 ha model. The costs of production and returns for both intensities of operation are similar in far north Queensland, but there are marked differences between the two regions which reflect the climatic constraint of being able to produce only one crop per year in the more southerly region.

The overriding conclusion to be drawn from the analysis is the high uncertainty of returns and risk involved in prawn farming. At current prices for the product, returns to prawn farming in Australia are adequate, but its profitability is very sensitive to price. With the prospect of further price falls in the future, returns to Australian prawn farmers may be reduced substantially unless savings in production costs can be achieved and/or production is switched to higher priced products. The effect on profitability of production of higher priced products —

such as higher priced species, live prawns or larger prawns — would require further research than was possible in this study. As the industry is still in a developmental stage it may well be possible to effect significant cost savings through increasing yields. The analysis showed that returns were more responsive to changes in yield than to reductions in feed costs. Also, unit costs may be substantially reduced and returns raised by increasing the size of the farm.

ACKNOWLEDGEMENTS

The authors with to acknowledge the support of the Fishing Industry Research and Development Council, which provided the research grant to ABARE that enabled Ms Treadwell and Dr Maguire to participate in this study.

The following people are acknowledged for their contribution in the compilation of this report. Mr Tim Jones, biologist: formerly Fisheries Branch, Queensland Department of Primary Industries (QDPI). Dr Noel Gillespie, Project Manager, Bribie Island Aquaculture Centre, QDPI. Mr Noel Moore, Northern Queensland Manager, Fisheries Branch, QDPI. All 30 prawn farmers who responded to the telephone census. 22 prawn farmers who attended the group assessment meetings at South Johnston Research Station, Queensland, and Palmers Island, New South Wales. Mr Barry Smith, Defiance Research P/L, Toowoomba, Queensland.

LITERATURE CITED

ABARE 1989. Commodity outlook: Fisheries products. Agriculture and Resources Quarterly 1(4): 410–412.

ALLAN, G.L. 1989a. New South Wales prawn production up. Austasia Aquaculture Magazine 4(5): 23–25.

1989b. Results from commercial and experimental prawn farming ponds in New South Wales during 1988/89. 51–57. In J. Paynter and N. Preston (eds) 'Proceedings Fourth Annual Conference Australian Mariculture Association. Brisbane'.

ALLAN, G.L. AND MAGUIRE, G.B. 1988. Prawn farming research in model ponds. 88–96. In J. Paynter and N. Preston (eds) 'Proceedings of the Australian Mariculture Association Third Annual Conference. Lismore, NSW'.

ANON, 1988. Shrimp culture in Asia. Globefish Highlights (FAO, Rome). 4(88): 6.

ANON, 1989. Shrimp prices extremely weak. Globefish Highlights (FAO, Rome). 4(89): 3–7.

BATTAGLENE, T. AND KINGSTON, A. 1990. Poor outlook for prawns - Japanese market downturn persists. Australian Fisheries 49(6): 34-36

CHEN, J.C., LIU, P.C. AND LIN, Y.T. 1989. Culture of *Penaeus monodon* in an intensified system in Taiwan. Aquaculture 77: 319–328.

COOK, J. AND LIGHTFOOT, C. 1987. Economics of brackishwater prawn farming. 85–100. In P.Sloane (ed.) 'Prawn farming for profit — Potential for success'. (SCP Fisheries Consultants P/L: Sydney).

GRIFFIN, W.L., HANSON, J.S., BRICK, R.W. AND JOHNS, M.A. 1981. Bioeconomic modelling with stochastic elements in shrimp culture. Journal of World Mariculture Society 12(1): 94–103.

GRIFFIN, W.L., LAWRENCE, A. AND JOHNS, M. 1986. Economics of penaeid culture in the Americas. 151–160. In Y. Taki, J.H. Primavera, and J.A. Llobrera (eds) 'Proceedings First International Conference on the culture of penaeid shrimp/prawns'. (South-east Asian Fisheries Development Center: Iloilo, Philippines).

HANDLEY, P. AND MOORE, J. 1989. Business affairs — Asian shrimp culture industry. Far Eastern Economic Review October 5: 96–100.

HANSON, J.S., GRIFFIN, W.L., RICHARDSON, J.W. AND NIXON, C.J. 1985. Economic feasibility of shrimp farming in Texas: An investment analysis for semi-intensive pond grow-out. Journal of World Mariculture Society 16: 129–150.

HARDY, F. 1985. The economics of prawn farming on the New South Wales coast. 22–24. In 'Prawn farming open day, Wollongbar'. (Department of Agriculture New South Wales: Sydney).

HATCH, V., SINDELAR, S., ROUSE, D. AND PEREZ, H. 1987. Demonstrating the use of risk programming for aquacultural farm management: the case of penaeid shrimp in Panama. Journal of the World Aquaculture Society 18(4): 260–269.

HEASMAN, M.P. 1984. Marine prawn farming in Australia: lessons from the past and prospects for the future. 1–14. In B.R. Pollock and R.H. Quinn (eds) 'The potential of aquaculture in Queensland'. (Queensland Department of Primary Industries Conference and Workshop Series, QC83012: Brisbane)

HOLLIN, D. AND GRIFFIN, W.L. 1986. Preliminary economics of shrimp mariculture in Texas. vii, 1–37. In G.W. Chamberlain, M.G. Haby and R.J. Miget (eds) 'Texas shrimp farming manual —

An update on current technology'. (Texas A&M University System: Corpus Christi. TX).
HUANG, H.J., GRIFFIN, W.L. AND ALDRICH, D.V. 1984. A preliminary economic feasibility analysis of a proposed commercial penaeid shrimp culture operation. Journal of World Mariculture Society 15: 95–105.
JUAN, Y.S., GRIFFIN, W.L. AND LAWRENCE, A.L. 1988. Production costs of juvenile penaeid shrimp in an intensive greenhouse raceway nursery system. Journal of the World Aquaculture Society 19(3): 149–160.
KINGSTON, A.G., SMITH, P. AND BEARE, S. 1990. 'Japanese seafood demand'. Paper presented to 34th Annual Conference of the Australian Agricultural Economics Society, University of Queensland, Brisbane 13–15 February. 33p.
KWEI, L.C. 1989. Prawn culture in Taiwan: what went wrong? World Aquaculture 20(2): 19–20.
LAWRENCE, A.L. AND HUNER, T.V. 1987. Penaeid shrimp culture in the United States: a brief overview stressing species, seed production, and grow-out. 31–41. In C.J. Sindermann (ed.) 'Reproduction, maturation, and seed production of cultured species'. US Department of Commerce, NOAA Technical Report, NMFS 47.
MAGUIRE, G.B. AND ALLAN, G.L. IN PRESS. Shrimp culture industry in Australia. In A. Fast and J.L. Lester (eds) 'Culture of marine shrimp: Principles and practices'. (Elsevier).
MAGUIRE, G.B. AND LEEDOW, M.I. 1983. A study of the optimum stocking density and feed rate for school prawns (*Metapenaeus macleayi*). Aquaculture 30: 285–297.
MAGUIRE, G.B., WISELY, B. AND SKEEL, M.E. 1981. Cultivation of the Sydney rock oyster *Crassostrea commercialis* (Iredale and Roughley) in prawn farming ponds. Aquaculture 24: 63–75.
MCKEE, D.A., LAWRENCE, A.L. AND GRIFFIN, W.L. 1989. Stocking strategies and an investment analysis for producing *Penaeus setiferus* as a live bait-shrimp on the Texas Gulf Coast. Journal of the World Aquaculture Society 20(2): 72–80.
O'SULLIVAN, D. 1990. 'Status and prospects for Australian aquaculture (1989–90)'. (Dosaqua: Mowbray, Tas.) 67p.
PARDY, C.R., GRIFFIN, W.L., JOHNS, M.A. AND LAWRENCE, A.L. 1983. A preliminary economic analysis of stocking strategies for penaeid shrimp culture. Journal of World Mariculture Society 14: 49–63.
PARKER, J.C. AND HAYENGA, W.A. 1979. An analysis of the investment considerations for penaeid shrimp mariculture in pond systems. (Texas A&M University Publication: Corpus Christi, Texas). 44p.
POTTER, M. AND JONES, T. 1990. Prawn farming in Australia. Agricultural Science 3(2): 23–24.
ROBERTSON, C.H. 1988. Prawn farming in Queensland — problems and progress so far. 17–27. In L.H.Evans and D.O'Sullivan (eds) 'Proceedings First Australian Shellfish Aquaculture Conference'. (Curtin University of Technology: Perth). 390p.
ROSENBERRY, B. 1990. 'World shrimp farming 1989'. (Aquaculture Digest: San Diego, CA). 28p.
SCURA, E.D. 1987. Review of world prawn farming. 1–12. In P. Sloane (ed.) 'Prawn farming for profit — Potential for success'. (SCP Fisheries Consultants Australia P/L: Sydney).
SHANG, Y.C. 1983. The economics of marine shrimp farming: a survey. 7-19. In G.L. Rogers, R. Day and A. Lim (eds) 'Proceedings First International Conference on warm water aquaculture — Crustacea'. (Brigham Young University, Hawaii Campus: Laie, Hi).
TREADWELL, R.F. AND WOFFENDEN, K. 1984. 'Estimating returns from growing some new horticultural crops'. Paper presented to the 28th Annual Conference of the Australian Agricultural Economics Society, University of Sydney, 7-9 February. 13p.
WICKINS, J.F., 1976. Prawn biology and culture. Annual Review Oceanography Marine Biology, 14: 435-507.
YANG, J., 1987. Cost analysis of a prawn grow-out farm. Append. 10–15. In P.Sloane (ed.) 'Prawn farming for profit — Potential for success'. (SCP Fisheries Consultants Australia P/L: Sydney).